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BRAZIL TENSILE STRENGTH TESTS ON SEA ICE - A DATA REPORT.(U)
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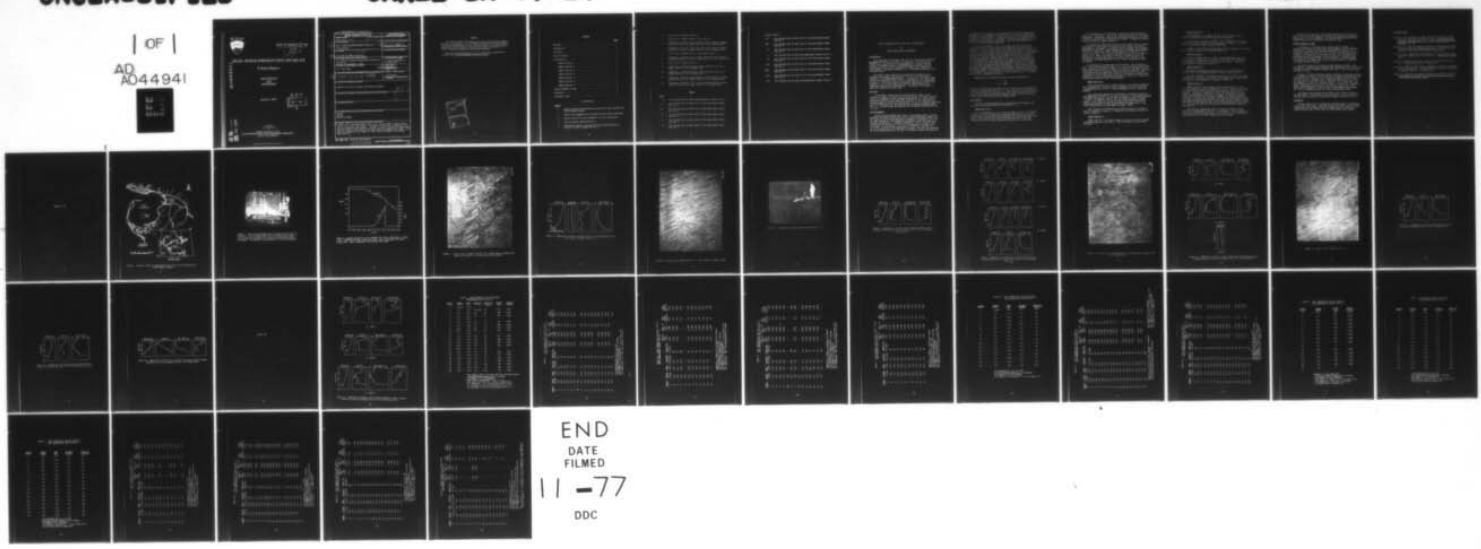

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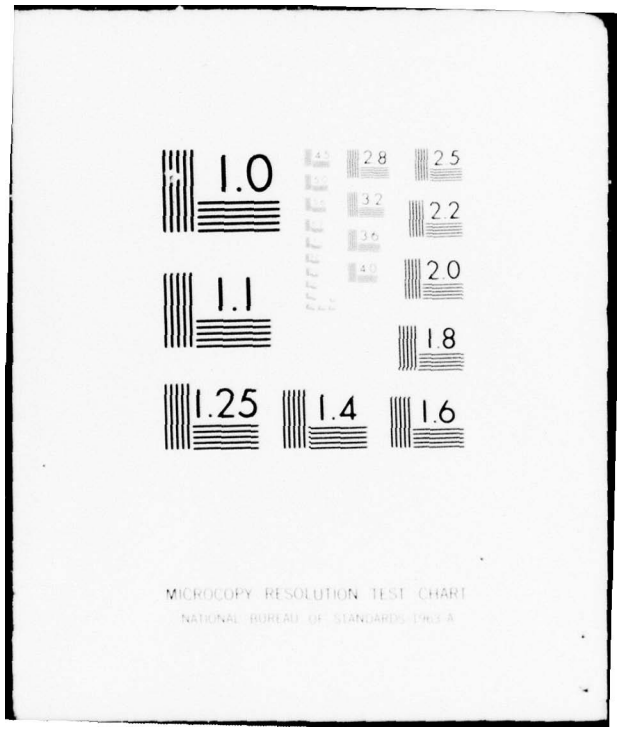
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BRAZIL TENSILE STRENGTH TESTS ON SEA ICE

A Data Report

Austin Kovacs
and
John Kalafut

August 1977

Prepared for
U.S. COAST GUARD
By
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In March 1970 drop penetrometer tests in sea ice were made by Sandia Laboratories for the U.S. Coast Guard. In support of this study, properties of the sea ice penetrated were measured. The data collected included ice temperature, salinity, brine volume, density and Brazil tensile strength versus depth. The data are presented in this report in both tables and graphs as a permanent data source.

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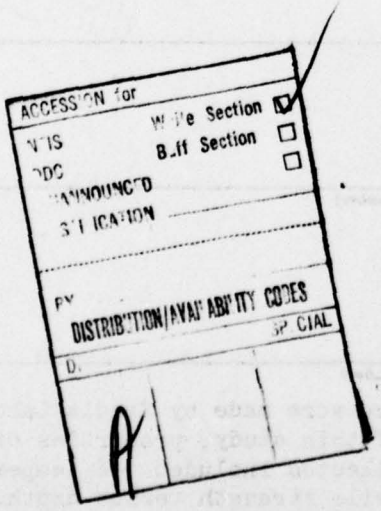
PREFACE

This report presents the results of a joint study by Austin Kovacs, Research Civil Engineer, of the Foundations and Material Research Branch, Experimental Engineering Division, and John Kalafut, Electrical Engineer, Engineering Services Branch, of the Technical Services Division, U.S. Army Cold Regions Research and Engineering Laboratory.

This study was performed for the U.S. Coast Guard, under MIPR No. Z-70099-02553, Military Geographic Analysis Project.



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Brazil Strength Tests on Sea Ice - A Data Report

by

Austin Kovacs and John Kalafut

Introduction

From 18 February to 18 March 1970, the U.S. Coast Guard Icebreaker Northwind (WAGB 282) was assigned for operations in the Bering and Chukchi Seas. The mission of the Northwind was to support research programs by USACRREL (pressure ridge morphology investigations) and Sandia Laboratories (sea ice penetrometer study) and to undertake a transportation feasibility analysis, i.e., a northward penetration into the Chukchi Sea.

The Sandia study consisted of determining the feasibility of measuring the thickness and strength of sea ice using instrumented, telemetric, air-dropped penetrometers. In support of this study, CRREL obtained data characteristics of the ice penetrated by the instrumented projectile. These data include the measured temperature, salinity and strength of the ice with depth and the brine volume computed from temperature and salinity determinations. In addition, ice density vs. depth was obtained at several sites.

Test Site

In selecting a field site for the penetrometer study, it was desirable to choose a location free from the chaotic structures (rafting, ridging and hummocking) that accompany drifting sea ice. Such terrain would make location of the impact site difficult if not impossible and likewise hamper or prevent the determination of sea ice thickness properties. The location selected for the study was Port Clarence and Brevig Lagoon (Fig. 1). The drop zones were selected for the general smoothness of the ice cover.

Test Procedures

Using a motorized CRREL auger (Fig. 2) cylindrical cores, 7.6 cm in diameter, were taken from the ice cover at each penetrometer impact site. The length of the core was measured to determine ice thickness. The core was then prepared for the appropriate temperature, salinity, density, or strength determination. To measure temperature, 1/8 in. diameter holes were drilled to the center of the core at preselected locations along its length. Into each hole in succession a thermistor (accurate to $\pm$0.1C) was inserted and the temperature recorded. Salinity was determined by first melting sections of the core in individual sealed containers and

then measuring the salinity of the water with the aid of a conductivity instrument. Brine volumes were calculated from the related temperature and salinity determinations. Vernier gages were used to measure section dimensions to one-tenth of a centimeter. A triple beam balance was used to measure specimen weight to one gram. From these measurements the density of the section was determined.

The tensile strength of the ice was determined by the Brazilian (Brazil) test which is also known as the diametral compression test. In preparing the test specimen, the initial cores were cut into lengths of 5 to 8 cm. A Vernier gage was used to measure the length L and the diameter D of the resulting cylinder. Each specimen was subjected to a diametral compressive force P by placing the specimen between the converging platens of a hydraulic loading machine (Fig. 2). The upper platen was rigidly attached to a load cell while the lower platen upon which the test specimen rested, was attached to the hydraulic ram. When actuated, the ram lifted the test specimen upward against the platen of the load cell from which the applied force was measured. Three linear variable differential transformers (LVDTs) spaced equally around the lower platen were used to measure the deflection sustained by the specimens under load and the ram speed. An oscillograph was used to provide a graphic record of the applied load and deflection vs. time during each test. A typical test record is presented in Figure 3.

The equation for computing the Brazil tensile strength σ_B is

$$\sigma_B = \frac{2P}{\pi DL} .$$

It should be noted that the Brazil test is only useful for determining a "tensile" strength index for sea ice. Test results are not a measure of the uniaxial tensile strength of ice. A more detailed discussion of the test can be found in Shook (1963), Malhotra (1967), Brown and Trollope (1967), Nevel (1969) and Mellor and Hawkes (1971).

Test Results

The first six penetrometers were dropped over Port Clarence, and the seventh was dropped over Brevig Lagoon (Fig. 1).

Impact Site No. 1

An air photograph of the ice cover at impact site No. 1 is shown in Figure 4. The ice in which the penetrometer came to rest was at the intersection of an area which had undergone both rafting and shear deformation. The blocks in the rafted lobes were less than 15 cm thick, indicating that the ice had undergone deformation at an early age.

On 24 February the ice thickness 1 m west of the impact hole was found to be 1.94 m thick. The ice was "firm" when cored. No voids were encountered. Temperature, density and salinity determination are listed in Table I along with the calculated brine volume. A graphical presentation of the above is shown in Figure 5.

As expected the temperature of the ice was coldest near the surface, decreasing with depth until it reached the sea ice-water equilibrium temperature at the bottom. The density varied throughout the thickness from 0.88 to 0.93 g/cm^3. This fluctuation is not unusual as the density of sea ice is most often found to range between 0.87 and 0.94 g/cm^3 within an ice sheet. The salinity decreased with depth down to approximately 0.6 m. Below this depth the salinity averaged just over 5‰. Fluctuation of the salinity profile is common and is related to the growth rate, thickness and age of the ice. Brine volume was as shown in Figure 5.

On 28 February the penetrometer was recovered. The thickness of the ice was then measured and found to be 3.32 m through the penetrometer hole. Because of the depth difference, the profiles in Figure 5 do not adequately represent the ice in which the projectile impacted. Additional core analysis was not undertaken because of the structure and depth variability of the deformed ice in the area and because the near surface properties of the ice had undergone change as a result of 10° warmer air temperatures during the days following impact.

Impact Site No. 2

Aerial and ground views of impact site No. 2 are shown in Figures 6 and 7 respectively. The ice cover was undeformed plate ice varying in thickness from 1.21 to 1.23 m. Three centimeters of snow covered the surface.

Core information gathered on 24 February is presented in Table II and graphically in Figure 8. As shown in Figure 8, ice strength decreases with depth from about 4.5 kg/cm^2 near the surface to about 3.5 kg/cm^2 1 m below. As expected, the ice near the bottom becomes noticeably weaker. This is due to an abrupt increase in porosity which can be determined indirectly for any plane by taking the square root of the brine volume within the plane (Weeks and Assur, 1966).

Data collected on 25 February are listed in Tables III through V and on 27 February in Table VI. Graphically the tabulated results are shown in Figure 9.

Impact Site No. 3

Impact site No. 3 is shown in Figure 10. The ice at this site was undeformed plate ice 1.25 m thick. Four centimeters of snow covered the area.

Impact Site No. 4

The undeformed ice at impact site No. 4 (Fig. 10) was 1.26 m thick; ten centimeters of drifted snow covered the area.

Core data were obtained on 1 March. This information is listed in Tables III through IX and is shown graphically in Figure 11. The data at this site follow trends previously discussed.

A sample from the snow cover was found to have a density of 0.54 g/cm^3 and a failure strength of 0.3 kg/cm^2 (Table VII).

Impact Site No. 5

The ice at impact site No. 5 (Fig. 12) was undeformed plate ice 1.29 m thick. Drifted snow, 13 cm deep, covered the site. Core data were taken on 27 February 1 m from the point of impact. These data are presented in Table X and Figure 13.

Impact Site No. 6

Measured ice thickness of impact site No. 6 varied from 1.29 to 1.33 m. The ice was undeformed plate ice with a 4-cm snow cover.

Core data obtained on 27 February are listed in Table XI and shown in Figure 14. Similarly, data taken on 28 February are listed in Tables XII through XIV and graphically presented in Figure 15.

Impact Site No. 7

Impact site No. 7 was located in Brevig Lagoon (Fig. 1). The ice was undeformed and had a thickness of 1.14 m. Core data were taken on 2 March under weather conditions which adversely affected core analysis. The low air temperature (-13°C) and high winds (20+ knots) caused the temperature of the core to change. In addition, blowing snow quickly covered the core and instrumentation, making analysis impractical. Two cores were analyzed. The data from the second core are not presented because they were obtained under rapidly worsening weather, the effect of which made the data totally unrepresentative of the in-situ ice. The data obtained from the first core are presented in Table XV and Figure 16.

Note that the temperature profile in Figure 16 shows a sudden decrease in temperature at the 0.5 to 0.75-m depth. This is believed due to core cooling discussed above. The dashed line is considered more representative of the in-situ temperature at this depth.

Note also the very low salinity measured between the 0.2 and 0.3-m depth. The core at this depth was found to have large brine drainage cavities up to 0.5 cm in diameter. No drainage from these cavities was observed when the core was removed from the ice sheet.

General Comments on Data

A few aspects of the data herein deserve general comment. As expected the Brazil test results show the strength of sea ice decreases with depth as a result of increasing temperature and porosity; the porosity of bubble free sea ice is for all intent and purposes directly related to the square root of the brine volume. For a more detailed discussion of this relationship as well as an overall synopsis on sea ice, see Weeks and Assur (1966). The fluctuation in tensile strength with depth is not uncommon and like the salinity profile is related to the growth history of the ice.

The time to failure for the Brazil test samples is listed in the data tables. Although values varied between the extremes of 0.4 and 0.7 sec., the time to failure in general remained very close to the overall average of 0.48 or 0.5 sec.

Because of valving difficulty and our inability to remove all the air in the hydraulic lines, it was not possible to maintain the same ram speed from test to test. However, the ram speed did remain constant during the load phase of individual tests. Ram speed varied from a low of 3.5 to a high of 8.0 cm per sec (see data tables). For the most part, ram speed remained close to the overall average of 5 cm per sec. Findings by Mellor (unpublished data) indicate that the rate sensitivity of the Brazil test performed on ice at the above speed range is approximately 5%. This is considered within the bounds of experimental error.

The deflection at failure for the Brazil tests is also listed in the data tables. These values varied from 0.033 to 0.07 cm but for the most part were very close to the overall average of 0.044 or 0.04 cm.

Discussion

Further analysis of the information presented herein is beyond the scope of this data report. Although time did not permit a more thorough investigation of ice properties at all impact sites, the data do in general describe the ice into which the penetrometers were dropped.

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Shook, W.B. (1963) Critical Survey of Mechanical Property Test Methods for Brittle Materials. Air Force Materials Laboratory, Technical Documentary Report No. A SD-TDR-63-491.

Weeks, W.F. and Assur, A. (1966) The Mechanical Properties of Sea Ice, Proceedings of Conference on Ice Pressures Against Structures, Laval University, Quebec, Canada.

Figures 1-16

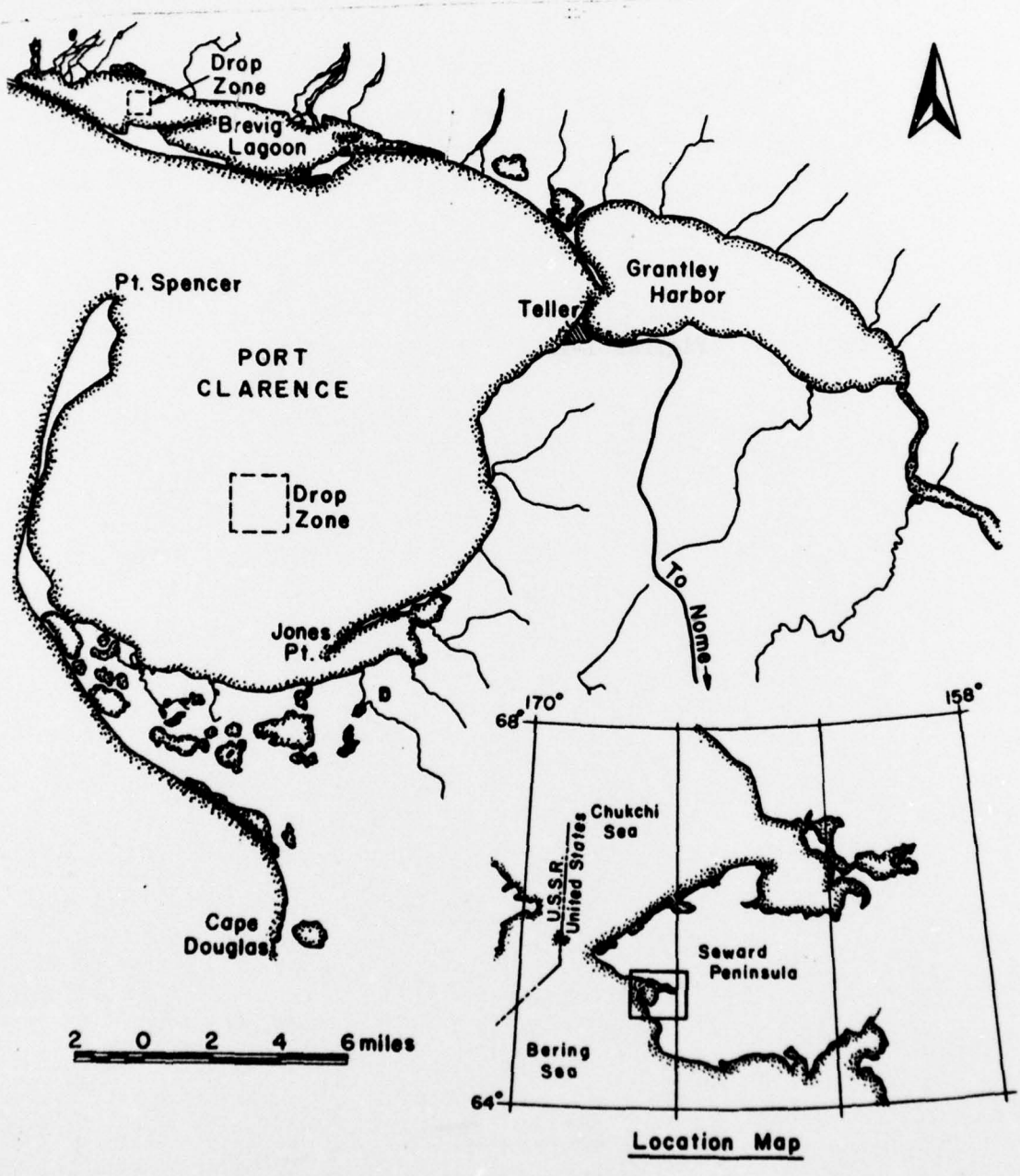


Figure 1. General location of penetrometer drop zones in Port Clarence and Brevig Lagoon, Alaska.

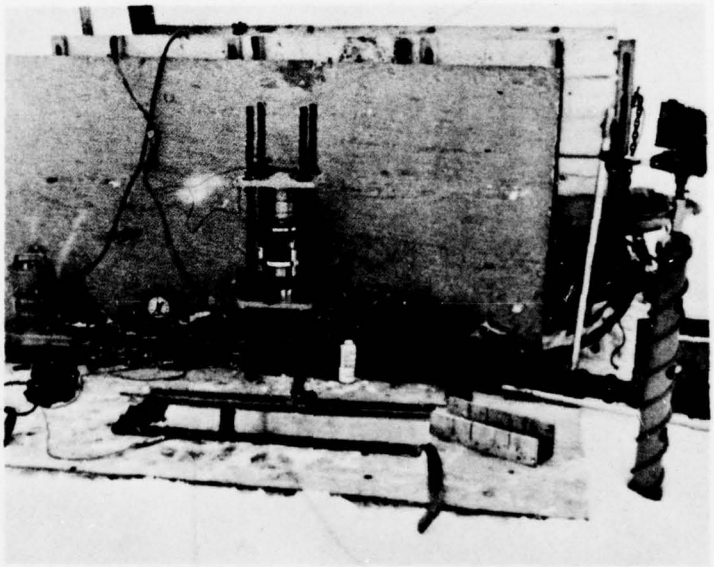


Figure 2. Some of the equipment used to gather and test sea ice specimens. On the extreme right is the motorized CRREL auger. A core is shown in the process of having its temperature profile determined. The hydraulic testing machine is in the background.

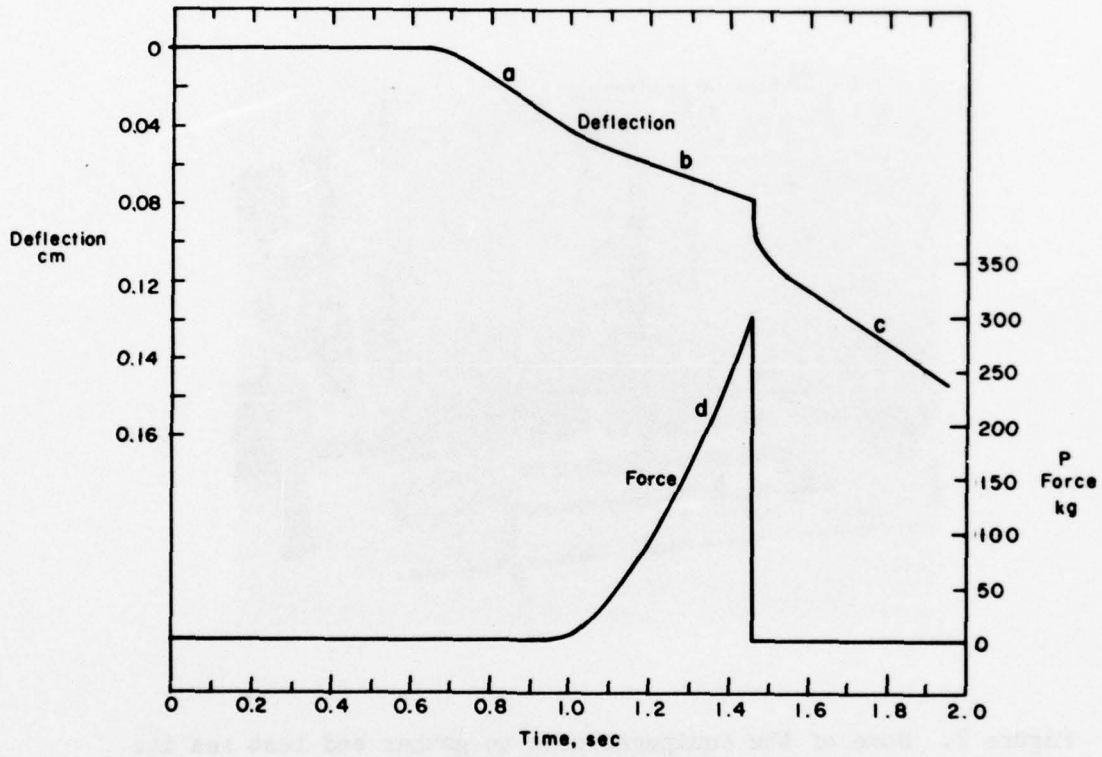


Figure 3. Typical record of a test, specimen 9 of core 3 from drop 6. (Note: a and c represent ram speed under zero load. Line b represents ram speed during test. Line d represents load build-up with time).

Figure 4. Sea ice scene at Impact Site No. One. Arrow points to impact hole which was enlarged to facilitate projectile removal.

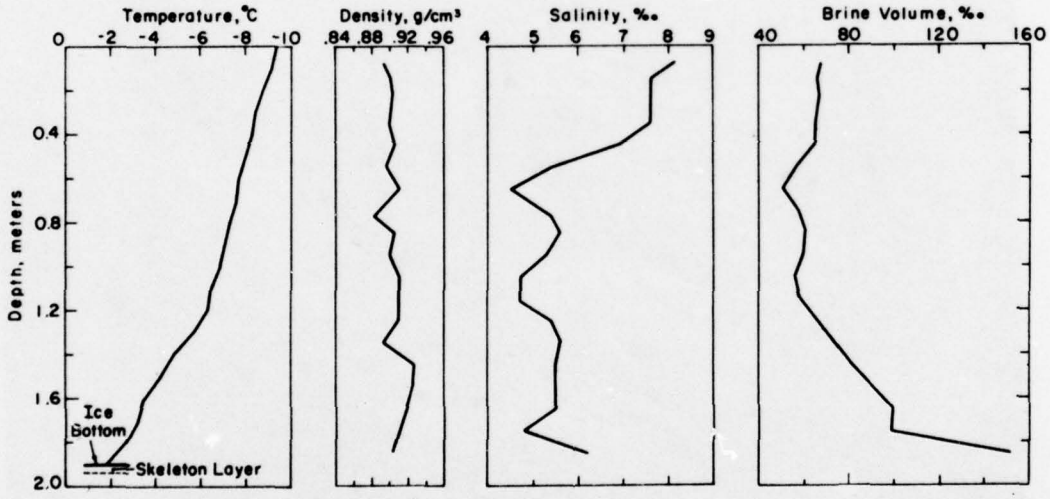


Figure 5. Temperature, density, salinity and brine volume profiles of sea ice 1 m west of Impact Site No. 1.

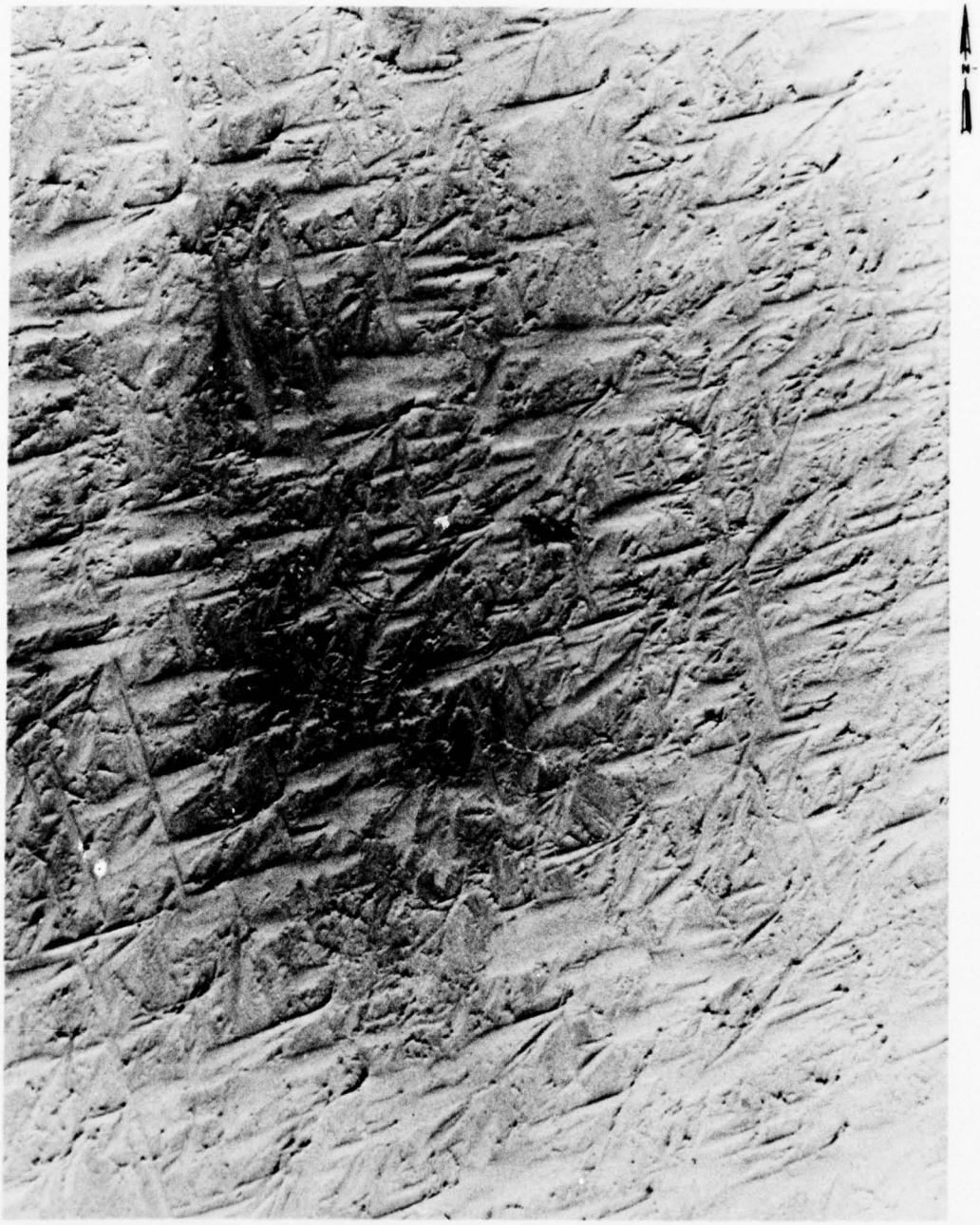


Figure 6. Aerial view of Impact Site No. 2. Arrow points to impact crater.

Figure 7. Ground view of impact crater at drop zone no. 2.

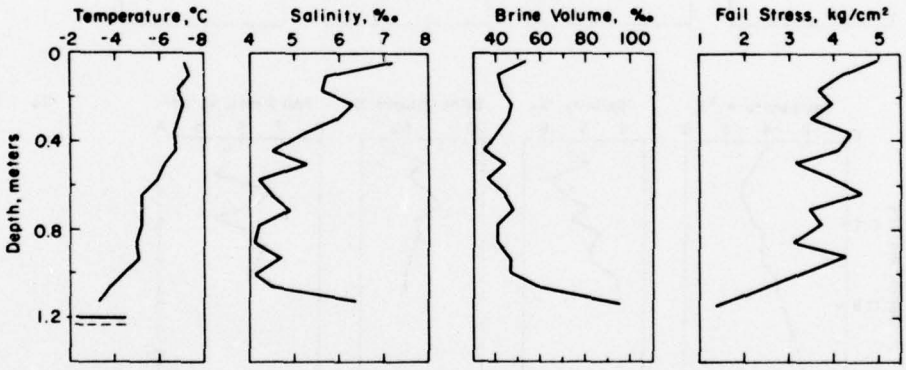


Figure 8. Temperature, salinity, brine volume and Brazil tensile strength profiles of sea ice at Impact Site No. 2 on 24 February 1970 (core 1).

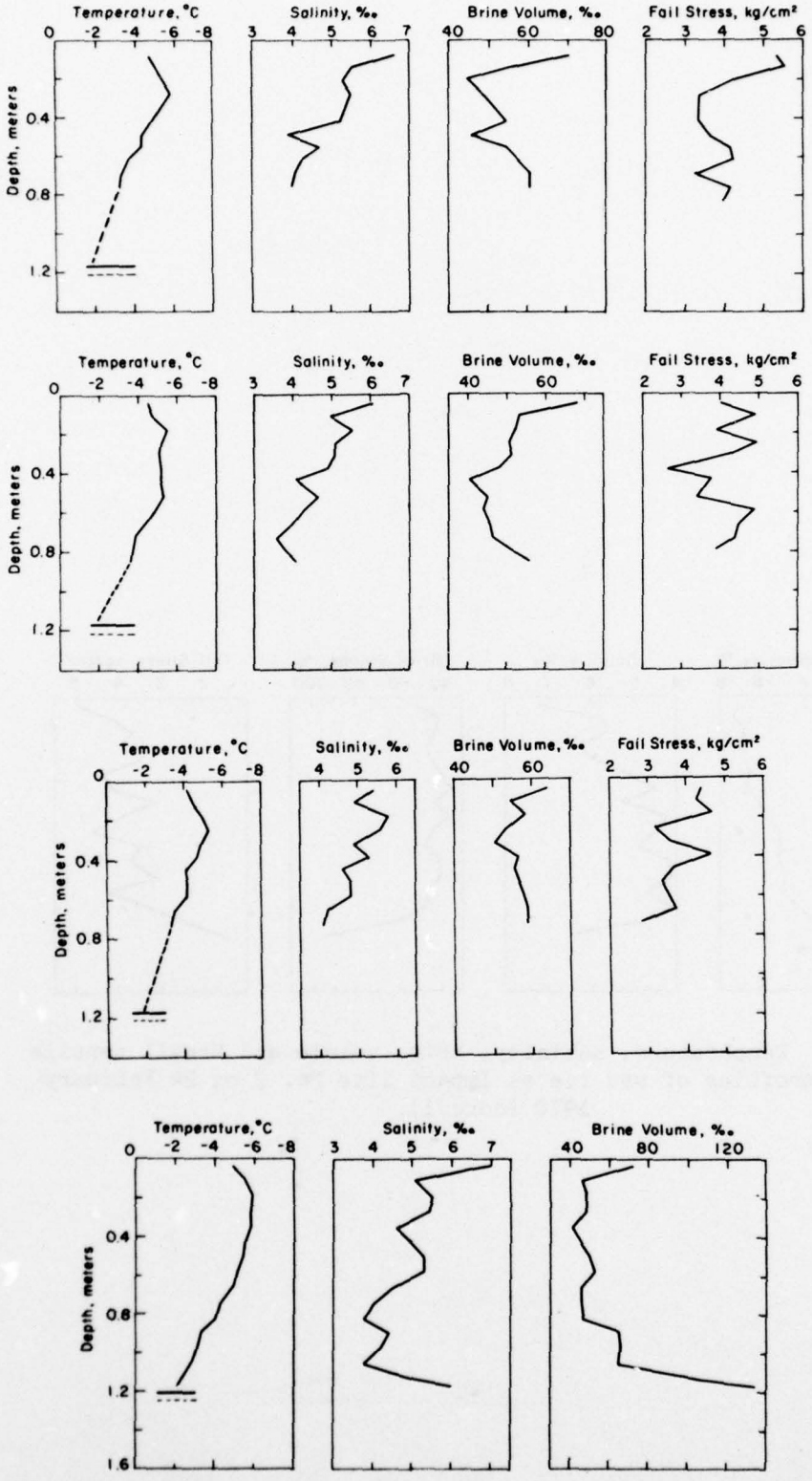
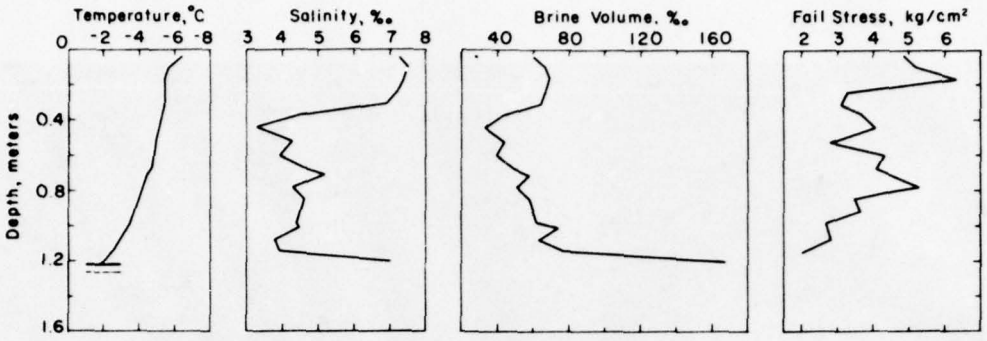
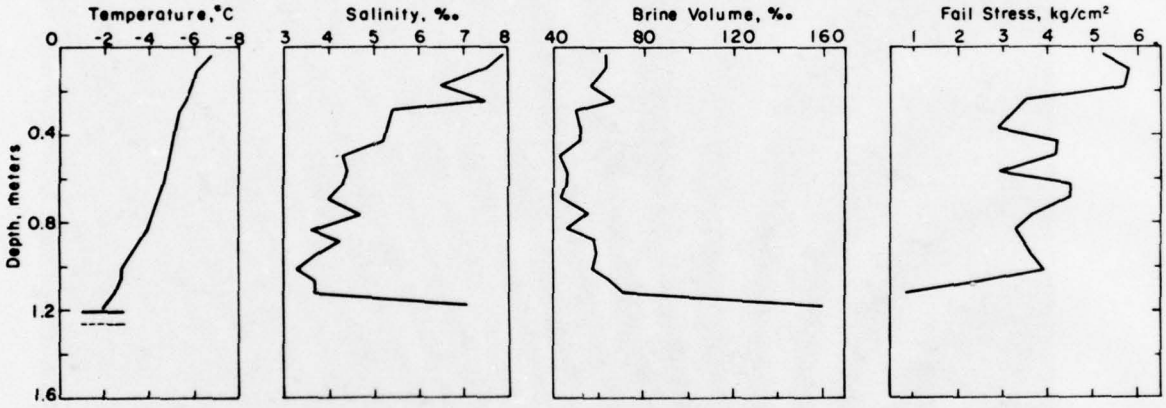


Figure 9. Temperature, salinity, brine volume and Brazil tensile strength profiles of sea ice at Impact Site No. 2 on 27 February 1970.

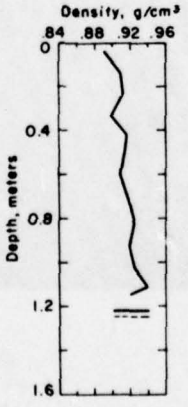
Figure 10. Aerial view of Impact Site No. 3 (lower arrow) and Impact Site No. 4 (upper arrow).



a. Core 1



b. Core 2



c. Core 3

Figure 11. Temperature, salinity, brine volume, density and Brazil tensile strength profiles of sea ice at Impact Site No. 4 on 1 March 1970.

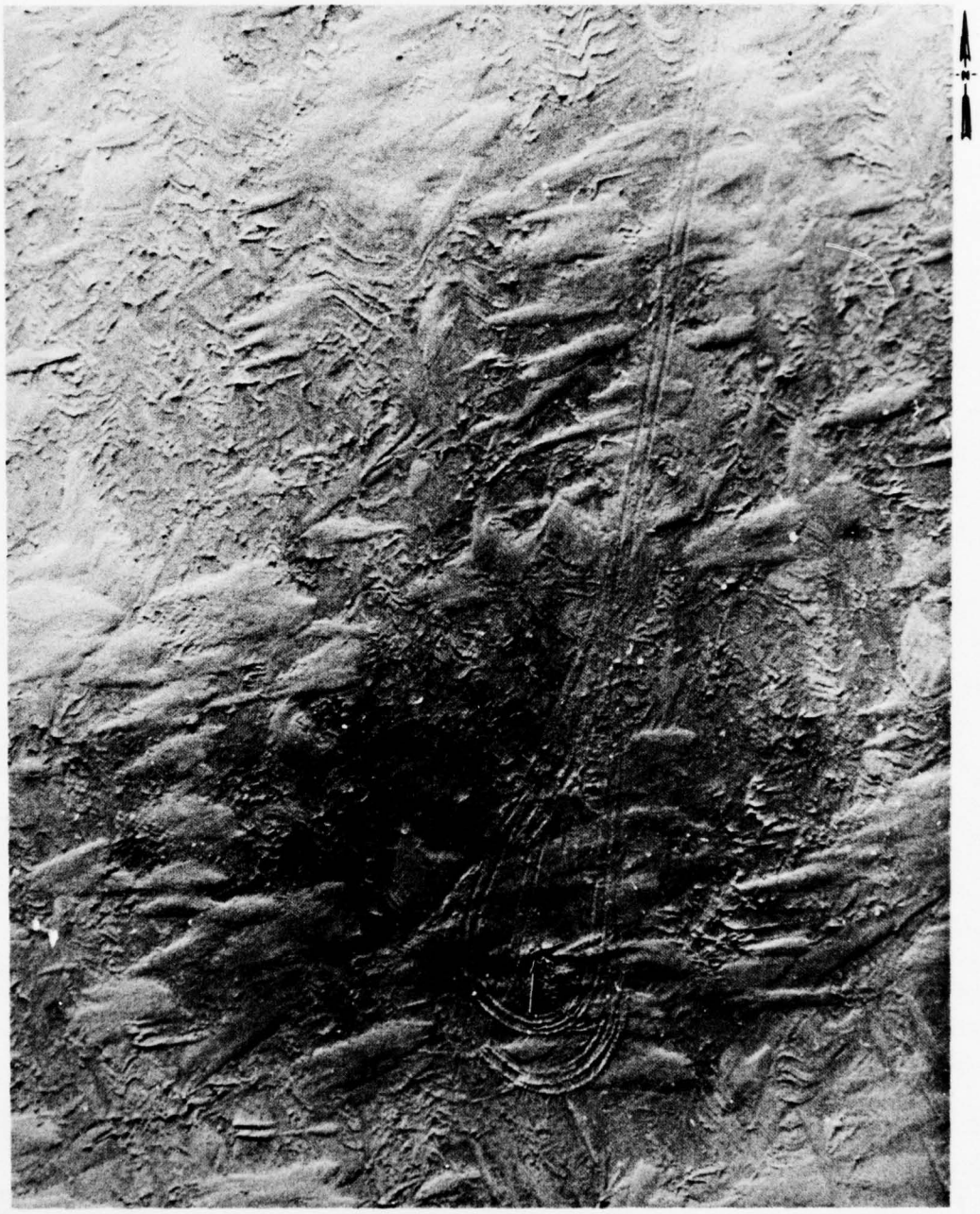


Figure 12. Aerial view of Impact Site No. 5.

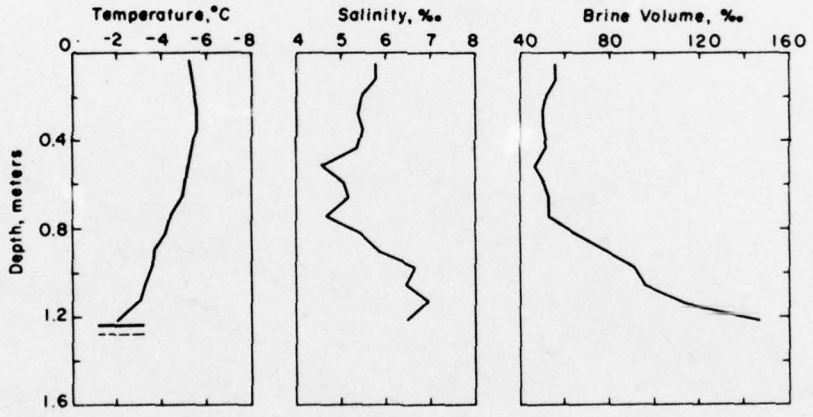


Figure 13. Temperature, salinity and brine volume profiles of sea ice at Impact Site No. 5 on 27 February 1970.

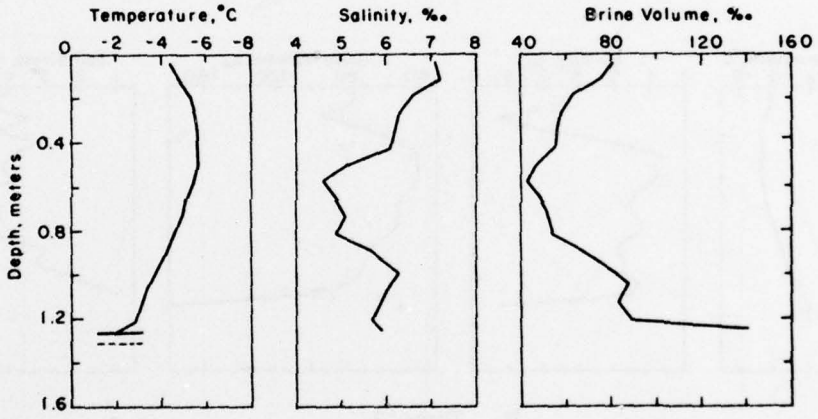


Figure 14. Temperature, salinity and brine volume profiles of sea ice at Impact Site No. 6 on 27 Feburary 1970 (core A).

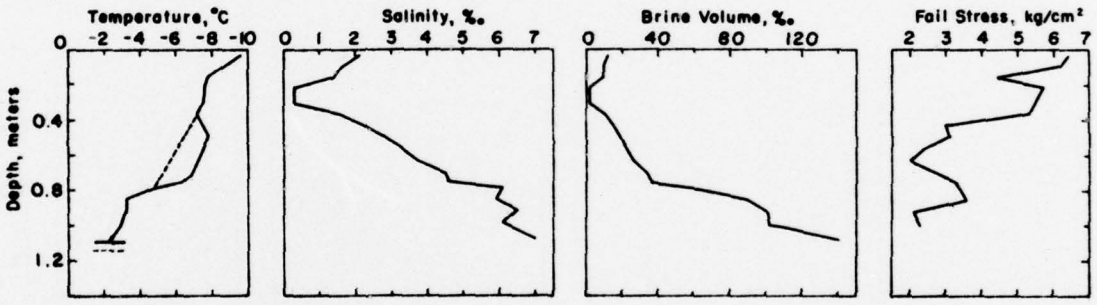
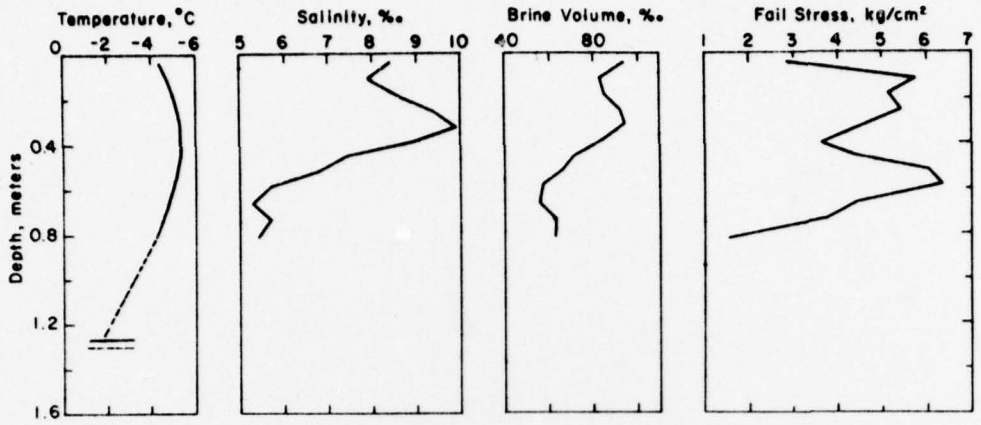
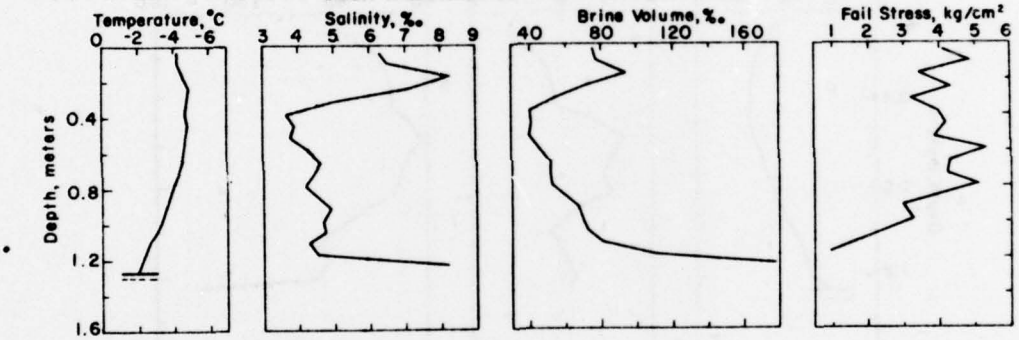


Figure 16. Temperature, salinity, brine volume and Brazil tensile strength profiles of sea ice at Impact Site No. 7 on 2 March 1970.

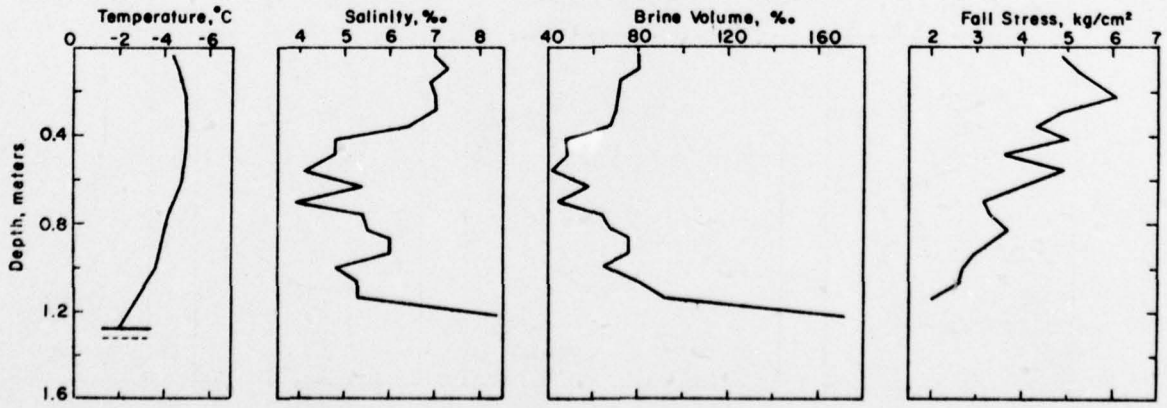
TABLES I-XV



a. Core 1



b. Core 2



c. Core 3

Figure 15. Temperature, salinity, brine volume and Brazil tensile strength profiles of sea ice at Impact Site No. 6 on 28 February 1970.

TABLE I. PORT CLARENCE SEA ICE DATA FROM PENETROMETER IMPACT SITE NO. 1

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL. (0/00)	WEIGHT (g)	DENSITY (g/cm^3)
1	5.0 cm	-9.3C	-	-	-	-
2	4.9	-9.3	8.1 0/00	48	200	0.893
3	9.5	-9.1	7.6	46	388	0.902
4	4.1	-8.7	7.6	47	168	0.904
5	6.0	-8.7	-	-	-	-
6	9.9	-8.4	7.0	45	404	0.900
7	9.4	-8.0	6.9	45	388	0.906
8	9.9	-7.8	5.4	37	402	0.896
9	10.0	-7.6	4.5	31	415	0.910
10	5	-7.5	-	-	-	-
11	6.5	-7.4	5.4	38	261	0.884
12	9.3	-7.2	5.6	41	382	0.905
13	9.5	-7.0	5.3	40	387	0.899
14	10.3	-6.7	4.7	36	425	0.909
15	10.0	-6.4	4.7	38	-	-
16	9.6	-6.0	5.4	46	397	0.911
17	6.1	-5.2	5.6	54	249	0.894
18	9.8	-4.5	5.5	61	412	0.927
19	9.5	-3.8	5.5	71	398	0.925
20	9.9	-3.4	5.5	80	412	0.918
21	9.2	-2.9	4.8	78	380	0.910
22	9.9	-2.2	6.2	132	405	0.902

Core length 190 cm +4 cm of "SK" (SK = Skeleton Layer)
2 mm loss between samples due to cutting
All samples 7.6 cm in diameter
Snow cover at penetrometer hole. 10 cm
Core taken on 24 Feb 70 1 m west of impact hole
Air temperature -8C, Wind approximately 8 knots
Ice thickness center of penetrometer hole 3.32 m
Ice thickness 1 m east of penetrometer hole 3.3 m

TABLE II. PORT CLARENCE SEA ICE DATA (CORE 1)
FROM PENETROMETER IMPACT SITE NO. 2

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.3cm	-7.1C	7.2 0/00	53 0/00	0.48	0.050	5.8	4.95
2	6.6	-7.3	5.7	41	0.40	0.043	5.8	4.15
3	6.6	-6.8	5.6	43	0.41	0.045	5.5	3.63
4	6.6	-7.0	6.3	47	0.46	0.040	4.6	3.97
5	6.6	-6.8	5.9	45	0.56	0.045	4.6	3.45
6	6.6	-6.6	5.1	40	0.43	0.045	5.5	4.31
7	6.6	-6.7	4.5	35	0.45	0.045	5.2	4.08
76	3.0	-	-	-	-	-	-	-
8	6.7	-6.2	5.3	44	0.35	0.035	4.9	3.06
9	6.6	-5.9	4.2	36	0.42	0.043	4.6	4.90
10	6.6	-5.2	4.5	44	0.41	0.040	4.7	4.57
11	6.6	-5.2	4.9	48	0.38	0.038	4.7	3.45
12	6.7	-5.2	4.2	41	-	-	5.2	3.69
13	6.6	-5.0	4.1	41	0.40	0.043	5.5	3.08
14	6.6	-5.1	4.7	47	0.50	0.050	5.8	4.34
15	6.7	-4.4	4.1	47	0.48	0.053	6.4	3.35
16	6.6	-3.8	4.5	59	0.41	0.048	5.8	2.47
17	6.8	-3.3	6.4	95	-	-	-	1.33

Ice thickness 120 cm +3.5 cm "SK"
2 mm loss between samples due to cutting
All samples 7.6 cm in diameter
Core taken on 24 February 70 1 m from impact hole
Air temperature -2C, Wind approximately 35 knots

TABLE III. PORT CLARENCE SEA ICE DATA (CORE 2)
FROM PENETROMETER IMPACT SITE NO. 2

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.5cm	-4.7C	6.6 0/00	71 0/00	0.52	0.048	5.2	5.34
2	6.6	-5.0	5.5	56	0.50	0.040	4.5	5.54
3	6.8	-5.4	5.3	45	0.43	0.040	4.6	4.28
4	6.6	-5.8	5.5	49	-	-	5.2	3.37
5	6.6	-	-	-	-	-	-	-
6	6.6	-4.8	5.2	54	0.40	0.038	4.7	3.37
7	6.7	-4.3	3.9	45	0.41	0.040	4.6	3.64
8	6.7	-4.3	4.7	54	0.41	0.038	4.7	4.16
9	6.6	-3.7	4.3	57	0.46	0.043	5.4	4.21
10	6.6	-3.3	4.1	61	0.44	0.043	5.2	3.73
11	6.6	-3.2	4.0	61	0.44	0.043	5.2	4.19
12	6.6	-	-	-	0.47	0.048	5.4	3.98

Sample No. 1 starts 2.5 cm below ice surface
Ice thickness 117 cm +4 cm "SK"
2 mm loss between samples due to cutting
All samples 7.6 cm in diameter
Core taken on 25 February 70 1 m from impact hole
Air temperature +12C Wind approximately 35 knots

TABLE IV. PORT CLARENCE SEA ICE DATA (CORE 3)
FROM PENETROMETER IMPACT SITE NO. 2

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.6cm	-4.5C	6.1 0/00	68 0/00	0.48	0.048	5.4	4.02
2	6.6	-4.7	5.0	53	0.54	0.050	5.0	4.97
3	6.7	-5.5	5.6	52	0.46	0.045	4.9	3.92
4	6.5	-5.2	5.2	51	0.48	0.043 q	4.7	4.97
5	6.0	-5.1	5.2	52	0.41	0.040	5.2	4.24
5b	1.0	-	-	-	-	-	-	-
6	6.6	-5.2	4.9	48	-	-	-	2.59
7	5.2	-5.1	4.0	40	0.42	0.043	5.8	3.80
7b	2.0	-	-	-	-	-	-	-
8	6.7	-5.3	4.7	45	0.42	0.043	4.9	3.40
9	6.5	-4.9	4.3	44	0.42	0.038	4.7	4.92
10	6.6	-4.4	4.0	45	0.47	0.045	5.0	4.52
11	6.7	-3.8	3.6	47	0.52	0.050	4.9	4.42
12	6.6	-3.7	3.8	51	0.51	0.050	6.1	3.92
13	4.5	-3.6	4.1	56	-	-	-	-

Sample No. 1 starts 1 cm below ice surface
Ice thickness 117 cm +4 cm "SK"
2 mm loss between samples due to cutting
All samples 7.6 in diameter
Core taken on 25 February 70 1 m from impact hole
Air temperature +2C, Wind approximately 35 knots

TABLE V. PORT CLARENCE SEA ICE DATA (CORE 4) FROM PENETROMETER IMPACT SITE NO. 2.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.7cm	-4.2C	5.4 0/00	64 0/00	0.44	0.040	5.2	4.42
2	6.6	-4.5	4.9	54	0.42	0.040	5.2	4.26
3	6.7	-5.0	5.8	59	0.50	0.050	5.2	4.65
4	6.6	-5.3	5.6	54	0.41	0.040	5.5	3.20
5	6.6	-4.9	4.9	50	0.44	0.040	5.2	3.60
6	6.6	-4.7	5.3	57	0.49	0.045	5.5	4.63
7	6.7	-4.1	4.6	56	0.41	0.040	4.6	3.69
8	6.6	-4.2	4.8	57	0.45	0.045	5.2	3.44
9	6.6	-4.1	4.8	58	0.42	0.040	4.9	3.58
10	6.6	-3.5	4.2	60	0.40	0.040	5.5	3.74
11	6.9	-3.4	4.1	59	0.42	0.045	6.4	2.81

Sample No. 1 starts 1 cm below ice surface
Ice thickness 117 cm +4cm "SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken on 25 February 70 1 m from impact hole
Air temperature +2C, Wind approximately 35 knots

TABLE VI. PORT CLARENCE SEA ICE DATA (CORE 5)
FROM PENETROMETER IMPACT SITE NO. 2.

SAMPLE	LENGTH	TEMP. (C)	SALINITY (0/00)	BRINE VOL. (0/00)
1	7.6cm	-4.9	7.0	72
2	7.6	-5.6	5.1	46
3	7.6	-5.9	5.5	48
4	7.6	-5.8	5.4	48
5	7.6	-5.8	4.6	41
6	7.6	-5.5	5.0	46
7	7.6	-5.4	5.3	50
8	7.6	-5.1	5.3	53
9	7.6	-4.9	4.5	46
10	7.6	-4.3	4.0	46
11	7.6	-4.0	3.8	47
12	7.6	-3.3	4.4	65
13	7.6	-3.1	4.2	66
14	7.6	-2.8	3.8	66
15	7.6	-2.3	5.0	104
16	3.8	-2.1	5.9	134

Ice thickness 119 cm +4 cm "SK"
2 mm loss between samples due to cutting
All samples 7.6 cm in diameter
Core taken on 27 February 70 1 m from impact hole

TABLE VII. PORT CLARENCE SEA ICE DATA (CORE 1)
FROM PENETROMETER IMPACT SITE NO. 4.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
a*	5.5cm	-6.4C	-	-	-	-	8.6	0.28
1	6.4	-6.2	7.3 0/00	60 0/00	0.59	0.050	4.3	4.93
2	6.6	-5.7	7.5	67	0.58	0.045	4.0	5.19
3	6.6	-5.4	7.4	69	0.60	0.050	4.1	6.40
4	6.7	-5.4	7.2	67	0.48	0.045	4.6	3.30
5	6.6	-5.4	6.9	64	0.46	0.040	4.4	3.11
6	6.7	-5.3	4.5	43	0.50	0.043	4.6	3.72
7	6.7	-5.1	3.3	33	0.49	0.040	3.8	4.11
8	6.7	-5.0	4.3	44	0.50	0.045	4.3	2.81
9	7.0	-4.8	3.9	41	0.53	0.040	4.0	4.29
10	5.9	-4.7	4.6	49	0.40	0.035	4.3	4.14
11	4.3	-4.4	5.2	58	-	-	-	-
12	6.6	-4.1	4.3	52	0.58	0.048	4.3	5.33
13	6.6	-3.9	4.6	58	0.48	0.043	4.3	3.51
14	6.9	-3.7	4.5	60	0.55	0.050	4.4	3.64
15	6.4	-3.5	4.4	62	0.48	0.048	5.3	2.71
16	3.0	-3.3	5.0	74	-	-	-	-
17	6.8	-3.0	3.8	63	0.52	0.053	5.3	2.79
18	6.5	-2.4	3.9	77	0.47	0.050	6.1	2.05
19	9.8	-2.0	7.0	168	-	-	-	-

*Sample a is from snow cover (density $0.545 g/cm^3$)
Ice thickness 122 cm +4 cm of "SK"
2 mm space between samples due to cutting

All samples 7.6 cm in diameter
Core taken 1 March 70 1 m from impact hole
Air temperature -6C, Wind 5-10 knots
10 cm snow cover at impact site

TABLE VIII. PORT CLARENCE SEA ICE DATA (CORE 2) FROM PENETROMETER IMPACT SITE NO. 4.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.6cm	-6.4C	7.9 0/00	64 0/00	0.67	0.058	4.4	5.24
2	6.6	-6.2	7.5	63	0.63	0.053	4.1	5.76
3	6.9	-5.9	6.5	56	0.61	0.050	4.1	5.73
4	5.9	-5.7	7.5	67	0.50	0.050	5.5	3.48
5	4.0	-5.4	5.4	51	-	-	-	-
6	7.0	-5.2	5.3	52	0.50	0.050	4.6	2.93
7	6.2	-5.1	5.2	52	0.50	0.043	4.4	4.23
8	6.5	-5.0	4.3	43	0.50	0.045	4.1	4.15
9	6.6	-4.8	4.4	46	0.43	0.043	4.9	2.93
10	5.9	-4.8	4.3	46	0.51	0.045	4.6	4.51
11	6.1	-4.6	4.0	44	0.51	0.043	4.4	4.49
12	6.6	-4.2	4.7	55	0.50	0.040	4.1	3.74
13	6.7	-4.0	3.6	45	0.49	0.045	4.7	3.29
14	4.6	-3.6	4.3	58	-	-	-	-
15	6.7	-3.2	3.8	59	0.51	0.045	4.7	3.62
16	6.6	-2.8	3.3	57	0.53	0.048	4.9	3.89
17	6.9	-2.8	3.7	65	0.67	0.071	-	2.52
18	6.6	-2.5	3.7	71	0.40	0.043	5.6	1.82
19	11.0	-2.0	7.1	160	-	-	-	-

Ice thickness 120 cm +6 cm "SK"
2mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken on 1 March 70 1 m from impact hole
Air temperature -10C Wind 5-10 knots
10 cm of snow cover at impact site

TABLE IX. PORT CLARENCE SEA ICE DATA (CORE 3)
FROM PENETROMETER IMPACT SITE NO. 4.

SAMPLE	LENGTH (cm)	WEIGHT (g)	DENSITY (g/cm^3)
1*	7.6	193	0.545
2	9.0	364	0.892
3	9.0	371	0.909
4	9.0	372	0.911
5	9.7	395	0.898
6	9.0	374	0.916
7	9.1	377	0.913
8	9.0	371	0.909
9	12.4	517	0.919
10	1.0	-	-
11	9.1	381	0.923
12	9.1	379	0.918
13	9.0	377	0.923
14	9.0	384	0.940
15	3.4	142	0.920
16	7.5	-	-

*Sample 1 is from snow cover
2 mm space between samples due to cutting
All samples 7.6 cm in diamter
Core taken on 1 March 70 1 m from impact hole
Air temperature -10C, Wind 5-10 knots
10 cm snow cover at impact site

TABLE X. PORT CLARENCE SEA ICE DATA FROM PENETROMETER IMPACT SITE NO. 5.

SAMPLE	LENGTH (cm)	TEMP. (C)	SALINITY (0/00)	BRINE VOL. (0/00)
1	7.6	-5.2	5.8	56
2	7.6	-5.3	5.8	56
3	7.6	-5.4	5.5	52
4	7.6	-5.5	5.4	50
5	7.6	-5.5	5.5	51
6	7.6	-5.3	5.4	52
7	7.6	-5.1	4.5	46
8	7.6	-5.0	5.1	52
9	7.6	-4.9	5.2	54
10	7.6	-4.4	4.7	53
11	7.6	-4.2	5.5	65
12	7.6	-3.7	5.9	79
13	7.6	-3.6	6.7	92
14	7.6	-3.3	6.5	96
15	7.6	-3.0	7.0	114
16	7.6	-2.1	6.5	148

Ice thickness 125 cm +5 cm "SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken 27 February 70 1 m from impact hole
13 cm of snow cover at impact site

TABLE XI. PORT CLARENCE SEA ICE DATA (CORE A)
FROM PENETROMETER IMPACT SITE NO. 6.

SAMPLE	LENGTH (cm)	TEMP. (C)	SALINITY (0/00)	BRINE VOL. (0/00)
1	7.6	-4.4	7.1	81
2	7.6	-4.8	7.2	76
3	7.6	-5.3	6.6	63
4	7.6	-5.5	6.3	58
5	7.6	-5.6	7.2	56
6	7.6	-5.6	6.1	56
7	7.6	-5.6	5.1	46
8	7.6	-5.4	4.6	43
9	7.6	-5.1	4.9	49
10	7.6	-4.9	5.1	52
11	7.6	-4.5	4.9	54
12	7.6	-4.2	5.7	68
13	7.6	-3.8	6.3	82
14	7.6	-3.4	6.1	88
15	7.6	-3.1	5.9	93
16	7.6	-2.8	5.7	99
17	7.6	-2.0	5.9	142

Ice thickness 126 cm +5 cm "SK"
2mm Space between samples due to cutting
All samples 7.6 in diameter
Core taken 27 February 70 1 m from impact hole
4 cm of snow cover at impact site

TABLE XII. PORT CLARENCE SEA ICE DATA (CORE 1)
FROM PENETROMETER IMPACT SITE NO. 6.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.8(cm)	-4.4(C)	8.4(o/oo)	94(o/oo)	-	-	7.0	2.84
2	6.8	-4.8	7.9	83	0.60	0.058	5.0	5.81
3	6.6	-5.1	8.5	85	0.50	0.048	5.3	5.13
4	6.7	-5.2	9.4	92	0.50	0.048	5.3	5.45
5	6.7	-5.4	9.9	94	-	-	6.6	4.57
6	6.8	-5.4	8.9	84	0.49	0.055	7.0	3.62
7	6.7	-5.3	7.4	71	-	-	8.1	4.37
8	6.7	-5.2	6.8	66	-	-	4.6	6.13
9	6.9	-5.1	5.7	57	0.53	0.050	5.0	6.40
10	7.0	-4.8	5.3	56	0.45	0.043	5.3	4.45
11	6.5	-4.6	5.7	63	-	-	5.3	3.74
12	6.9	-4.2	5.4	63	0.37	0.040	7.0	1.54

Ice thickness 126 cm +3 cm "SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken 28 February 70 1 m from impact hole
Air temperature -2C, Wind 1-3 knots
4 cm of snow cover at impact site

TABLE XIII. PORT CLARENCE SEA ICE DATA (CORE 2)
FROM PENETROMETER IMPACT SITE NO. 6.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	5.6(cm)	-4.2(C)	6.3(o/oo)	75(o/oo)	0.56	0.050	5.0	4.07
2	7.0	-4.2	6.5	77	0.56	0.050	4.9	4.79
3	6.7	-4.6	8.5	94	0.54	0.045	4.4	3.40
4	4.0	-4.8	-	-	-	-	-	-
5	6.4	-4.9	7.1	71	0.52	0.043	4.6	4.28
6	6.8	-4.8	5.1	53	-	-	5.0	3.24
7	7.3	-4.7	3.7	40	0.58	0.053	4.3	4.01
8	6.9	-4.8	3.9	41	0.44	0.033	3.8	4.19
9	6.5	-4.8	3.8	40	0.45	0.033	4.0	3.86
10	6.6	-4.6	4.3	46	0.63	0.050	4.0	5.30
11	6.8	-4.5	4.6	51	0.56	0.048	4.3	4.25
12	7.0	-4.3	4.4	51	0.59	0.053	4.1	4.19
13	5.6	-4.0	4.2	52	0.60	0.050	4.1	5.02
14	6.0	-3.8	-	-	-	-	-	-
15	5.8	-3.6	4.9	57	0.51	0.048	5.0	2.95
16	6.3	-3.3	4.7	70	0.46	0.040	4.6	3.26
17	6.8	-3.0	4.5	73	0.44	0.043	5.0	2.40
18	5.8	-2.6	4.3	80	0.40	0.040	5.8	1.70
19	5.6	-2.4	5.4	108	0.38	0.045	6.4	0.88
20	-	-2.2	8.2	179	-	-	-	-

Ice thickness 127 cm +3 cm"SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken 28 February 70 1 m from impact hole
Air temperature -20, Wind 1-3 knots
4 cm of snow cover at impact site

TABLE XIV. PORT CLARENCE SEA ICE DATA (CORE 3) FROM PENETROMETER IMPACT SITE NO. 6.

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	6.7(cm)	-4.4(C)	7.0(0/00)	80(0/00)	0.47	0.035	4.6	4.85
2	6.4	-4.6	7.3	80	0.60	0.050	4.9	5.40
3	6.0	-4.8	6.9	72	-	-	-	-
4	6.1	-5.0	7.0	71	0.51	0.035	4.7	6.18
5	6.3	-5.1	7.0	70	0.45	0.040	5.0	4.87
6	6.3	-5.1	6.4	64	0.50	0.040	4.4	4.31
7	6.4	-5.0	4.8	48	0.60	0.050	4.7	5.00
8	7.1	-5.0	4.8	49	0.51	0.043	4.4	3.58
9	6.8	-4.8	4.1	42	0.54	0.045	4.1	4.93
10	6.3	-4.7	5.4	58	0.51	0.043	4.3	3.99
11	6.6	-4.4	3.9	44	0.50	0.045	4.9	3.11
12	6.5	-4.2	5.4	64	0.45	0.038	4.3	3.27
13	6.0	-4.0	5.5	68	0.42	0.035	4.4	3.67
14	4.0	-3.9	6.0	76	-	-	-	-
15	6.2	-3.9	6.0	76	0.50	0.048	5.0	2.87
16	6.8	-3.6	4.8	65	0.50	0.048	4.9	2.74
17	6.5	-3.2	5.3	81	0.45	0.045	5.5	2.57
18	6.3	-2.8	5.3	92	0.61	0.071	6.7	1.99
19	-	-2.3	8.4	172	-	-	-	-

Ice thickness 128 cm +5 cm "SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken 28 February 70 1 m from impact hole
Air temperature -2C, Wind 1-3 knots
4 cm of snow cover at impact site

TABLE XV. BREVIG LAGOON SEA ICE DATA FROM PENETROMETER IMPACT SITE NO. 7

SAMPLE	LENGTH	TEMP.	SALINITY	BRINE VOL.	TIME TO FAIL (sec)	DEFL. TO FAIL (cm)	RAM SPEED (cm/min)	FAIL STRESS (kg/cm^2)
1	5.3 (cm)	-9.6 (C*)	2.1 0/00	12 0/00	0.50	0.045	3.5	6.47
2	5.8	-8.6	1.6	10	0.40	0.035	4.4	6.17
3	6.4	-7.8	1.4	10	-	-	4.7	4.45
4	5.5	-7.6	0.3	2	-	-	4.1	5.67
5	9.5	-7.5	0.3	2	-	-	-	-
6	5.6	-7.2	1.6	12	-	-	4.6	5.29
7	6.3	-7.5	2.3	16	0.37	0.040	4.6	3.02
8	6.2	-7.8	2.8	19	0.36	0.040	5.2	3.12
9	6.6	-7.6	3.3	23	-	-	-	2.39
10	6.2	-7.3	3.7	27	-	-	6.4	2.08
11	6.4	-7.0	4.5	34	-	-	5.5	2.83
12	5.0	-6.4	4.6	37	-	-	5.5	3.27
13	3.0	-4.8	6.1	65	-	-	-	-
14	6.7	-3.2	5.9	90	-	-	5.3	3.62
15	6.6	-3.2	6.5	101	-	-	-	2.13
16	6.5	-2.9	6.1	102	-	-	6.7	2.28
17	13	-2.4	7.0	140	-	-	-	-

Ice thickness 109 cm +5 cm "SK"
2 mm space between samples due to cutting
All samples 7.6 cm in diameter
Core taken 2 March 70 1.5 m from impact hole
Air temperature -13C Wind 20+ knots and blowing snow

*Test temperature not necessarily in situ temperature - core temperature changing rapidly due to exposure to low air temperature and high wind.